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Citation for published version:
Gray, DS & Colucci-Gray, L 2014, 'Globalisation and the Anthropocene: The Reconfiguration of Science Education for a Sustainable Future', *Sisyphus — Journal of Education*, vol. 2, no. 3, pp. 14-31. https://doi.org/10.25749/sis.6543

Digital Object Identifier (DOI):
10.25749/sis.6543

Link:
Link to publication record in Edinburgh Research Explorer

Document Version:
Publisher's PDF, also known as Version of record

Published In:
Sisyphus — Journal of Education

GLOBALISATION AND THE ANTHROPOCENE: THE RECONFIGURATION OF SCIENCE EDUCATION FOR A SUSTAINABLE FUTURE

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ABSTRACT

In this article we discuss current impacts on the planet as a result of techno-scientific developments and neo-liberal policy. We argue that science education has an important role to play in supporting society to respond to new challenges ahead. However there needs to be a change to the way in which science is introduced in schools to raise awareness of complex global interconnectedness and our embeddedness in the natural (and increasingly altered) planetary cycles. Such awareness changes how we view the practice of science and the way in which science is presented in schools. Drawing on recent literature, this paper will present an argument for the reconfiguration of science education for a sustainable future.

KEY WORDS

Sustainability Science; Equity; Democracy.

SISYPHUS
JOURNAL OF EDUCATION
VOLUME 2, ISSUE 3,
2014, PP. 14-31

Globalisation and the Anthropocene: The Reconfiguration of Science Education for a Sustainable Future

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THE WORLD OF SCIENCE

> business as usual in science will no longer suffice, that the world at the close of the 20th century is a fundamentally different world from the one in which the current scientific enterprise has developed (Gallopin, O'Connor, Funtowicz & Ravetz, 2001, p. 237).

Citing Lubchenco (1998), Gallopin et al. (2001) were calling for a change in the method and practice of science arguing that the way in which the current scientific enterprise has described the world and influenced the cultural fabric of, largely Western, society could not be sustained. Lubchenco's (1998) call for a "New Social Contract for Science" indicated that such recognition of the need for change was coming from the scientific establishment itself. The (unwritten) social contract with science had been the expectation that substantial investment in science would result in winning the war (initially the Second World War and later the Cold War). The social contract and the privileged position of science had resulted in incredible understanding ranging from the discovery and detailed structure of the smallest organisms, an intricate and far reaching understanding of our bodies, and greater recognition of the complexity and interconnectedness of our world, to the extensive exploration of our universe and its history. However, Lubchenco went on to question whether the science that met these challenges in the past was prepared for the daunting challenges that face us in the future. At the time Jane Lubchenco was president of the American Association for the Advancement of Science, four years later Peter Raven, the then president of the AAAC stated: "We need new ways of thinking about our place in the world and the ways in which we relate to natural systems in order to be able to develop a sustainable world for our children and grandchildren" (Raven, 2002, p. 957).

The scientific establishment was beginning to take note of the drastic impacts the power of science had enabled mankind to inflict on the Earth. The list is long and serious: climate change, ozone depletion, water scarcity, meteorological instability, melting ice caps, mineral resources depletion, rainforest clearance, atmospheric pollution and so on. Such recognition prompted Paul Crutzen, a Nobel prize winning atmospheric chemist to suggest that we are living in a new geological epoch called the Anthropocene.

Such awareness, however, is not new and a number of other prominent scientists had already recognised the far reaching impact of human activity, perhaps one of the most notable and seminal being Rachel Carson with her book Silent Spring. Carson, a marine biologist and conservationist documented in her book the detrimental effect of chemical pollution on the environment, particularly on birds, and brought such concerns to everyday awareness. However, while Silent Spring helped to bring this to the attention of the general public, more than fifty years on the problems appear to be accelerating rather than being brought under control and diminishing. The most pressing problem today may be climate change, or as some would rather call it, the climate crisis. The level of atmospheric carbon dioxide as elaborated by the Intergovernmental Panel on Climate Change (IPCC, 2014) and presented by NASA (n.d.) is clearly not part of the natural global cycles as some would have us believe, but is in fact an anthropogenic effect. As stated in the IPCC report: "Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems" (IPCC, 2014, p. 5).

Thus climate change has been, it is suggested, caused largely by industrialisation over the last few hundred years and particularly as a result of the great acceleration (Steffen, Crutzen & McNeill, 2007; Steffen et al., 2004) in the second half of the twentieth century, giving rise to the widespread and significant impacts on human and natural systems. The impacts from the great acceleration, it is argued, are largely as a result of the scale and speed of modern technoscience (Jasanoff, 2002) coupled with the global hegemony of western neo-liberal economic policies and industry. This has resulted in dangerous and possibly irreversible, damage to our life-support system (Rockström et al., 2009). It has, however, also been suggested that humans have contributed in large part to the current state of global and local climate change in other more subtle and complex ways than through the mechanisms proposed by the IPCC (Bryce & Day, 2014).

The term Anthropocene was first advocated by biologist Eugene Stoermer in the 1980s but not popularised and put into print until he co-published an article with Nobel prize winning atmospheric chemist Paul Crutzen in a Global Change Newsletter in 2000. In this newsletter they presented some of the fundamental impacts that human technology and progress has had on the planet and stated:

> Considering these and many other major and still growing impacts of human activities on earth and atmosphere, and at all, including global, scales, it seems to us more than appropriate to emphasize the central role of mankind in geology and ecology by proposing to use the term "anthropocene" for the current geological epoch (Crutzen & Stoermer, 2000, p. 17).

It has long been recognised that science as a discipline does not exist in a vacuum, outside of either nature or social processes. Science is conducted by human beings on behalf of other human beings and/or an academic community, often at the directive of yet others. Scientists bring their own perspectives, values and attitudes to bear on the subject of their focus and these can often result in diverging opinions about courses of action or interpretation of data (Sarewitz, 2004).

These twinned and inter-related phenomena of globalisation and anthropogenically induced global change have, we believe, profound implications for the purpose and pedagogy of science education in our schools.

WHAT IS GLOBALISATION?

Before examining the issues relating to science education in the Anthropocene, it is necessary to first of all take a look at what is meant by globalisation and the impacts that modern day globalisation is having on the "three pillars" of sustainability the economic, social and environmental (Brundtland Commission, 1987), and subsequently the fabric of the planet. From here we propose to consider some general trends of globalisation made manifest in education systems around the world and then, more specifically to make our proposals for science education in the globalised world of the Anthropocene.

Altbach (2013), in considering what globalisation means for higher education suggested that it "implies the broad social, economic, and technological forces that shape the realities of the 21st century" (p. 7). Such elements include advanced information technology, new ways of financing higher education aligned with neoliberal economic agendas, and an acceptance of the principles of commercialisation and market forces. In addition globalisation presents the opportunity for unprecedented mobility of students and academics. Altbach also suggests that it gives rise to "the global spread of common ideas about science and scholarship, the role of English as the main international language of science, and other developments" (p. 7). While on the one hand this may provide beneficial opportunities and results, a view strongly endorsed by Charlton and Andras (2006), on the other hand it is also strongly condemned by others as the hegemonic spread of western ideology and culture at the expense of other perspectives, languages and knowledge and, as such, presents a threat to the world's cultural, linguistic and biocultural diversity (UNEP, 2001). Such a hegemony of largely Euro-American views, culture and language, further underpinned by Western European socio-cultural and philosophic history, risks stifling the bio-cultural diversity, and the importance of local and indigenous knowledge which has been demonstrated as being so important in human development over the millennia (Maffi, 2007).

Chiu and Duit (2011) describe globalisation as the processes of global (i.e. worldwide) distribution of ideas and goods, most significantly with regard to scientific, technological, economic and cultural products and developments. While the international spread of materials, goods, cultures and ideological perspectives has been prevalent throughout history, what has been more recently termed globalisation refers much more to economic globalisation based on a renewed (neo-)liberalism which is built on the ideological perspective of liberating individuals from state intervention to pursue economic self-interest. However, the limitations and damage of neoliberal economic thinking is increasingly recognised and has given rise to "new" and "ecological" economics which adhere to some fundamental principles, such as those embedded in the *Limits to Growth* (Meadows, Meadows, Randers & Behrens, 1972), of finite resources in a globally interconnected planet where the health and well-being of all living beings, as well as humans, and concomitant environment and social justice are fundamental to the future survival and sustainability of the planet. The new economics foundation, for example states that its purpose is "to bring about a Great Transition — to transform the economy so that it works for people and the planet" (New Economics Foundation, n.d.). The term Great Transition here is perhaps making reference to the work by Karl Polanyi (1944), *The Great Transformation*, which provided a foundation, along with the works of others such as K. William Kapp, Kenneth Boulding and Herman Daly, for the development of the modern school of thought of ecological economics.

Moore, Kleinman, Hess and Frickel (2011) define globalisation as a "descriptive characterization of an historical change in the scale of society" (p. 507). While acknowledging global phenomena throughout history, modern globalisation has largely resulted in the post-World War II scenario. Such changes are characterised by,

> in the political field (...) the increasing role of international governmental and nongovernmental organizations in organizing access to rights, identities, and material benefits; in the economic field to the increasing role of multinational corporations, and the interlocking of global financial institutions; and in the social field to changes in the volume and types of immigration and cultural flows (Moore et al., 2011, p. 507).

So we see that in different disciplines the term globalisation has nuanced meanings with some scholars theorising globalisation as ideology, some as a prevailing epoch, and others as process (Harvey, 2005; Tobin, 2011).

GLOBALISATION AND SCIENCE

There are contrasting views about what the implications are for globalisation and its influence on science, or science's influence on globalisation. As pointed out by Fensham (2011) the start of the 21st century resulted in a number of scientific and technological organisations identifying what they saw as "Grand Challenges and Opportunities". Environmental and health issues, reflecting societal concerns, figured prominently and can be seen as examples of society's need for a solution to issues frequently brought to public and political awareness through mass media and other technological communication such as social media. So, while these global issues provide a focus for the attention of science and politicians looking for "solutions", another side of the coin is the fact that the increasing scale and power of science and technology, coupled with huge financial investment, has actually contributed to many of these problems, such as increased CO_2 production which has greatly contributed to climate change, toxic pollution from overuse of agricultural chemicals (Shiva, 2014), and damage to the ozone layer as a result of the use of chlorofluorocarbons (CfCs). On a global scale Llewellyn Smith (2011) suggests that the global issues we now face (such as energy, food and water security; climate change; biodiversity; potential pandemics) are much more complex than other issues which have previously focused science, and the media's, attention such as ozone depletion and smallpox.

One aspect of globalisation and the grand challenges we face today such as global environmental change, food security and widespread poverty requires different approaches to the traditional monodisciplinary sciences. In other words it requires interdisciplinarity. Interdisciplinary thinking is becoming an integral feature of research as a result of four powerful "drivers" stated by Bammer (2013) as: the inherent *complexity* of nature and society, the *need* to explore problems and questions that are not confined to a single discipline, the *need* to solve societal problems and the power of new technologies. She goes on to say that the grandest of today's challenges are what are known as "wicked" problems, key elements of which are: a high degree of connectivity to other problems, making them effectively impossible to isolate; considerable uncertainty and ambiguity about the problem and the solutions, including poor-quality or missing data; multiple value conflicts and ideological, cultural, political, economic and other constraints; resistance to change because there are contradictory solutions, numerous possible intervention points and consequences that are difficult to imagine (Horn & Weber, 2007).

The characteristics of "wicked" problems, described by Horn and Weber as being "composed of inter-related dilemmas, issues, and other problems at multiple levels society, economy, and governance" (2007, p. 1) are similar to the problems that need to be addressed by a new form of science suggested by Funtowicz and Ravetz (1993), "post-normal" science.

Clearly referring to the Kuhnian notion of normal science, Funtowicz and Ravetz (1993, 1994) developed the idea of post-normal science to deal with the new challenges of complex science related issues where science is applied in conditions that are clearly not "normal" and there are high degrees of uncertainty and risk. In these typically facts are uncertain, values in dispute, stakes high and decisions urgent. The model proposed by Funtowicz and Ravetz is one which recognizes three levels of science engagement. Where both uncertainty and stakes are small, traditional research and expertise can do the job without having to pay any particular attention to value-laden considerations. When one or both of them is at a mid-level, there is a need to appeal to a wider professional consultancy. Post-normal science emerges when both uncertainty and decision stakes are high and the value-dimension and perceptions held by the stakeholders have to be taken into consideration (Boudourides, 2003). In other words there is an appeal to the "extended peer community" to seek a resolution to the tensions caused by the uncertainty.

One of the difficulties with the globalisation of science is the accusation that the science that is promulgated is a science built on a Euro-American model and perspectives, with a predominance of English as the medium of communication. It is also suggested that such infusion of western science is inextricably linked with a neoliberal globalisation and neoliberal economics resulting in the marginalisation of indigenous knowledge and the concomitant threat to bio-cultural diversity (UNEP, 2001). So on the one hand there are those who perceive globalisation, despite its inevitable problems, as being a desirable and beneficial trend (Charlton & Andras, 2006) "since it enables increased efficiency, effectiveness and capability of societies and thereby, potentially benefits most people most of the time" (p. 869). However, on the other hand others such as Jasanoff (2002) highlight the inherent difficulties with a simplistic and reductionist view of science and technology development. While science and technology have, she says, brought "hope of liberation from hunger, toil and disease" (2002, p. 255), their impacts can, conversely, prove to be devastating. The embracing of science and technology by business and politics as some kind of panacea for economic and social ills has resulted in some serious consequences. As she states:

> The transnational movement of science and the artefacts that embody scientific knowledge give rise to distinctive social and political problems, especially when societies that played no part in the design or construction of new

> technologies are forced to engage with technology's widening reach (Bijker et al., 1987; Jasanoff, 1994) (Jasanoff, 2002, p. 255).

This internationalisation of science and technology, Jasanoff suggests, while perhaps having very positive benefits also has the result of constraining people's power of self-determination, no less than legal regimes and financial markets. As a counterpoint to the idea that science is a "neutral" discipline she points out that technologies are "never developed in morally neutral spaces but are conceived and deployed within previous configurations of wealth and authority. Existing hierarchies reinscribe themselves with the aid of new instruments (…)" (2002, p. 258). For example, giant corporations, with the aid of complicit legal structures, use technologies to deskill workers and tighten control of the workplace (Noble, 1977). Similarly technologies have done little to change the position of women in families, with the basic division of labour much as it always has been (Cowan, 1983). Jasanoff provides other examples, from the Green revolution (Scott, 1985; Shiva, 1991), hazardous technologies and development of complex technologies (Winner, 1986), of how the old hegemonic structures, power and influence are further entrenched through the appropriation and use of science and technology, maintaining and even exacerbating rich-poor and north-south divides and have been implemented without meaningful democratic supervision and debate (Shiva, 1997).

The unintended consequences of science and technological development has been dramatically underscored in

> the succession of environmental problems that imprinted themselves on human consciousness during the last third of the twentieth century: pollution from pesticides and hazardous substances (Carson, 1962), acid rain from power plant emissions, ozone depletion through the use of seemingly benign chemical refrigerants, and climate change as a consequence of energy-consuming industrial and agricultural development (Jasanoff, 2002, p. 259).

So on the one hand we have the global impacts of science and technology as a result of the large power and scale of global level industrial processes, the exacerbation of global pandemics as a result of greater global communication and travel, recognition of the complexity of the planetary systems and the global movement of energy and materials as a result of human activity, massive increase in industrial agricultural processes ostensibly required to feed the growing population. All these require a reconsideration of the current practices of science, which in turn will have implications for the principles and practice of science education at all levels.

THE GLOBALISATION OF SCIENCE EDUCATION

While there has been some academic work examining globalisation and its general impact on education and teacher education, there has been little commentary with respect to this in the science education literature, although it is slowly gaining recognition (Carter, 2005). Underpinning the critiques of the influence of globalisation on science education is the need to recognise "expose" and "scrutinise" the neoliberal influences on science, which, Carter suggests, enhances the quality of theorising about the political influences in science education, and thus facilitating attempts to improve that education (Carter, 2014).

Yet while there is little acknowledgement of the relationship between globalisation and science education in the science education literature, global influences are made manifest in the incorporation of travelling policies linked to standardisation and marketization as suggested by Hartley (2002) and Ozga (2005). An example of the manifestation of globalisation within science education is typified by the spread of science education reform agendas embodied within movements such as "Science for All" and scientific literacy (Carter, 2005). Such globalisation has, suggests Carter, resulted in a homogenizing educational model. This model reflects Hartley's views of the marketization and standardisation of education which, in science education, takes the form of "self-regulation through curriculum and teaching standards coupled to sophisticated regimes of surveillance…" (Carter, 2005, p. 571). Thus the globalisation of science education, according to authors such as Bencze and Carter (2011), is founded on an economic model which reflects and lends weight to the predominant neo-liberal market economies and serves to preserve these traditional forms of privilege at the expense of more democratic and social agendas. Such a homogenisation and global acceptance of science education is in direct contrast to the new views of science emerging from fields such as science studies and recognition of the importance of other forms of knowledge that can actually contribute to a better understanding of our world and contribute to the science knowledge base (e.g. Aikenhead, 1996; Aikenhead & Ogawa, 2007). Thus academics and educators need to be aware of the global economic agendas that influence the way in which educational policies and subject content knowledge is mandated, as well as the influence such policies have on pedagogical practice which, suggested by Hartley (2002), is likely to lead to much more teacher centred and more "traditional" approaches to practice. Such traditional approaches tend to treat science as a body of knowledge that is independent of the sociocultural environment in which the practice of science takes place and therefore tends to ignore the impact that science and technological developments have on the planet, and the way in which, as Jasanoff points out, science as developed by policy and commerce, exacerbates the already entrenched rich/poor and north/south inequalities that exist in the world. Thus there is a need to critically examine science education's relationship to globalisation, to elaborate the different perspectives and consider the implications of those aspects that have direct impact on science classrooms (Astiz, Wiseman & Baker, 2002). What is apparent is that, while science education has seen a variety of initiatives aimed at raising awareness of the social and environmental impacts of science, such as Science and Technology Studies, and Science for Citizenship, science is, nevertheless still largely conducted in what can be described as a traditional format. As Tytler states:

> The emphasis is on conceptual knowledge, compartmentalised into distinct disciplinary strands, the use of key, abstract concepts to interpret and explain relatively standard problems, the treatment of context as mainly subsidiary to concepts, and the use of practical work to illustrate principles and practices. All these have been relatively constant features of science education across the 20th century and into the 21st (2007, p. 3).

Taking account of the current impact of big science and techno-science's partnership with commercial interests and the subsequent impact on the planets eco- and life support systems, suggests a need to reconfigure science education not just to cover simple science "facts" and "processes" but to raise awareness of the subtle ways in which science is used and abused for commercial gain at the expense of social and environmental well-being. As Carter suggests "researching globalisation's impact on science education could forge some new and different scholarship directions" (2005, p. 574) as well as developing alternative frameworks for reviewing some of science education's current tensions, ambiguities and paradoxes. Such a critical examination of the neoliberal and globalisation impact on science with the subsequent consequences for environment and biocultural diversity, and the influence on science education, forces us to deeply analyse and ask some hard questions about science education reforms. Who are they for and what purpose do they serve? What kind of science education do we want? Carter's view is that we should be working towards developing a science education that values non-commodified forms of knowledge, relationships, activities, and aspects of life, and that includes sustainability science, cultural recognition, and social redistribution in its agenda. Acknowledging that much of the form of this approach to science education has yet to be configured, an important part of its reconfiguration and development is in elaborating the relationship between globalisation and science education.

While Carter's view is very much critical of the impact that globalisation has had on education and science education others, such as DeBoer (2011), view the globalisation agenda from a different perspective. Acknowledging that international testing and comparisons such as TIMSS and PISA do take place, DeBoer asks whether there should be a move to build on these and develop international standards for global citizenship in science education while still providing scope for individual countries to pursue goals that are unique to their own setting. Bencze and Carter (2011), continuing the critique of neoliberalism and science education suggest that, currently, science education is largely influenced by neoliberal agendas and functions to produce future scientists as *producers* and compliant citizens as *consumers*. To counter this "undemocratic" and "highly problematic" use of education, they propose a theoretical framework for organising science and technology education to bring about a more just and sustainable world. The framework they propose is based on principles like holism, altruism, realism, egalitarianism and dualism. In short the framework for consideration of socio-scientific issues offers a marked contrast to the established hegemony of reductionist science coupled with neoliberal interests which serve largely the needs and desires of a few at the expense of the many and the environment. The contrast to this is to raise awareness of the holistic and interconnected nature of global problems, to encourage understanding of the disproportionate distribution of economic, cultural and social capital and to strive towards more egalitarian values. This Bencze and Carter term activist science and technology education and can thus be seen to be building on the proposal from Hodson (2003) who suggested that education in this domain of socio-scientific issues can occur at four levels of sophistication (Bencze & Carter, 2011). These are:

Level 1. Appreciating the societal impact of scientific and technological change, and recognizing that science and technology are, to some extent, culturally determined.

Level 2. Recognizing that decisions about scientific and technological development are taken in pursuit of particular interests, and that benefits accruing to some may be at the expense of others. Recognizing that scientific and technological development are inextricably linked with the distribution of wealth and power.

Level 3. Developing one's own views and establishing one's own underlying value positions.

Level 4. Preparing for and taking action [to address SSIs]

(Hodson, 2003, p. 655).

So we see there is a potential tension and conflict resulting from differing perspectives on science education and its purpose. On the one hand we have the global economic agenda and subsequent policy and assessment initiatives (e.g. PISA, TIMSS) which drives science education towards a homogenised and standardised approach with the tendency inherent in this approach towards conservative, traditional pedagogies largely dependent on memorisation and recall with some deference given to problem solving skills in the form of enactment of a "scientific methodology". On the other hand, we have the socio-environmental imperative and the anthropogenic impacts on the life support systems of the planet with, beyond any doubt, "warming of the climate system is unequivocal" (IPCC, 2014, p. 5) resulting in "the likelihood of severe, pervasive and irreversible impacts for people and ecosystems" (ibid., p. 7).

It can also be argued, and is also recognised, that the current science provision in schools is "content heavy with transmissive pedagogy" and much of the science curriculum is "irrelevant" (DCSF, 2008, p. 3). The current provision for science education is, arguably, unfit for the purpose of a science education required to fulfil multiple purposes for a globalised future. There is, perhaps, not a universal consensus as to what science education should look like but it will, by necessity need to be radically different to what is on offer just now. Perhaps such a future education can be imagined from the amalgamation of research and scholarly literature on science education along with suggestions from the IPCC's (2014) report on climate change. In the summary report they state that the educational options for social transformation in response to climate change are: "Awareness raising and integrating into education; Gender equity in education; extension services; sharing indigenous, traditional and local knowledge; participatory action research and social learning; knowledge sharing and learning platforms" (p. 26).

The interesting aspect of this statement is that it actually mirrors many of the themes that have emerged over the years in the science education literature. So, for example gender equity in education is well covered in the general educational research literature but has a particular significance in the STEM subjects because of the traditional dominance of boys taking the sciences in schools, particularly the physical sciences. This coupled with a general downward trend in the uptake of STEM subjects at Higher Education level has resulted in this being a key area for UK policy (DCSF, 2008).

Similarly as mentioned earlier Aikenhead (1996) and Aikenhead and Ogawa (2007) amongst others, have examined and raised awareness of the importance of traditional and indigenous knowledge in science education.

With respect to participatory processes and action research it could be argued that the field of education is far in advance of the natural sciences in this respect, although there are some tokenistic forms of participation being used in science projects in the form of citizen science projects. McFarlane (2013), for example, suggests that the call for a new science education requires a participatory pedagogy which "demands student-teachers' enquiry-based actions addressing issues that are socio-scientific and which underpin the human and technical elements of science learning as a field" (p. 38).

In essence it seems that with regard to the socially transformative potential of education the sciences, in the form of the IPCC, are just beginning to recognise what has been advocated in many of the more forward thinking science education publications for many years now. It could be the case that for once science education research has something to offer the pure sciences when it comes to social transformation. Now that this has been articulated by the IPCC it may be possible to apply more leverage to the policy makers to enable some radical changes to be enacted in secondary school science departments.

Such radical changes will require a substantial rethink of the way in which science is usually taught in schools. As Tytler suggests,

> Pedagogy, in a re-imagined science curriculum, will need to be more varied, more supportive of students' agency through more open tasks, increased discussion and negotiation of ideas, and involve more varied settings. Reform

of science education will need to include a substantial re-think of pedagogy, linked to content reform and teacher development (2007, p. 66).

As a final thought which has perhaps been given more urgency, and more poignancy, with the current climate crisis than when Dewy first stated this:

If we teach today as we taught yesterday, we rob our children of tomorrow
John Dewey (1916, p. 167).

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Received: December 8, 2014
Final version received: December 22, 2014
Published online: December 29, 2014